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Association of Ultraviolet Radiation Exposure with Dermatomyositis in a National Myositis Patient Registry

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Abstract

Objective—Dermatomyositis (DM) has been associated with geospatial differences in ultraviolet (UV) radiation, but the role of individual determinants of UV exposure prior to diagnosis is unknown.

Methods—We analyzed questionnaire data from 1350 adults in a U.S. national myositis registry (638 with DM, 422 polymyositis [PM], and 290 inclusion body myositis [IBM] diagnosed at ages 18–65 years), examining the likelihood of DM compared with PM and IBM diagnosis, in relation to self-reported sunburn history and job- and hobby-related sun exposures in the year prior to diagnosis. We estimated odds ratios (OR) and 95% confidence intervals (CI) using logistic regression adjusted for age, skin tone, and sex, to determine the association of individual UV exposures with DM diagnosis. We also evaluated the proportion of DM by maximum daily ambient UV exposure, based on UV-B erythemal irradiances for participant residence the year prior to diagnosis.

Results—DM was associated with sunburn in the year before diagnosis (two or more sunburns, OR=1.77; 95%CI 1.28, 2.43 vs. PM/IBM; one sunburn OR=1.44; 95%CI 1.06, 1.95) and with having elevated job- or hobby-related sun exposure (high OR=1.64; 95%CI 1.08, 2.49 or moderate exposure OR=1.35; 95%CI 1.02, 1.78 vs. low or no exposure). Ambient UV intensity was associated with DM in females (beta=3.97, P=0.046), but not overall.

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Conclusion—Our findings suggest that high or moderate personal exposure to intense sunlight is associated with developing DM compared with other types of myositis. Prospective research on UV exposure as a modifiable risk factor for DM is warranted.

The idiopathic inflammatory myopathies (IIM) are rare autoimmune diseases characterized by chronic muscle inflammation and classified into three major pathogenic subtypes—dermatomyositis (DM), polymyositis (PM), and inclusion body myositis (IBM) (1). Although the subtypes share phenotypic muscle weakness and chronic inflammation and certain genetic risk factors, patients with DM have photosensitive rashes and specific autoantibodies (anti-Mi-2, transcription intermediary factor 1 gamma [TIF-1γ], and melanoma differentiation-associated protein 5 [MDA5]) (2), whereas those with PM and IBM have no photosensitive rashes and have some autoantibodies not present in DM (2, 3). The prevalence of DM and PM peaks in childhood (4) and mid-life (ages 35–60 years), and these subtypes occur predominantly in females, whereas IBM is more common in men over age 55 years (5).

Among patients living in areas of greater environmental ultraviolet (UV) radiation globally and across the United States, studies have found geospatial differences in the proportion of DM to PM, as well as a greater proportion of myositis autoantibodies (anti-Mi2 and anti-TIF-1γ) associated with UV exposure proximal to diagnosis in DM (6–9). This consistent evidence across different populations is suggestive; however, none of those studies assessed individual-level exposures. Clinical studies of DM patients with documentation of frequent photosensitive rashes suggest some may have greater sensitivity to UV exposure (4), but the role of personal exposures and sun sensitivity in the risk of developing DM is not known.

We hypothesized that exposure to intense sunlight, such as levels that may cause sunburn, might trigger the development of DM. Using data from a national United States (U.S.) registry of myositis patients (10), we examined whether differences in sunburn and personal sun exposures in the year prior to diagnosis were associated with the development of DM compared with PM or IBM. We examined self-reported history of sunburn in the year prior to diagnosis and inferred the potential for intense personal exposures to UV radiation based on a systematic review of individually reported jobs and hobbies for elevated exposures to sunlight. We also considered the association of DM with ambient UV levels estimated from ozone and reflectivity data at participants' residential location at the time of diagnosis and explored whether ambient UV levels and individual sun sensitivity might modify the relationship of personal sun exposures with development of DM.

Materials and Methods

Population and sample

The development of the MYOVISION registry has previously been described (10). Potential study participants were initially contacted between December 2010 and July 2012 through The Myositis Association's national mailing list, study advertisements, and specialty clinics. After signing informed consent, participants completed an extensive questionnaire that included demographics, disease-related information, environmental exposures, and questions about work and hobby activities (10). Of 9211 participants contacted, 1956 (22%) returned

questionnaires, and 1806 met probable or definite Bohan and Peter criteria for DM or PM (11) or Griggs' criteria for possible IBM (12, 13). Although the registry includes patients with juvenile DM and PM, we did not include anyone in the current study who was under age 18 years or over age 65 years at the time of diagnosis, due to small numbers in those age groups and limited comparability with job and hobby patterns in adults in the prime working years. Because of changes in the methods used to assess ambient UV-B irradiance data, participants diagnosed prior to January 1, 1990, were also excluded. Thus, the final sample included 1350 adults with IIMs—638 (106 males, 532 females) with DM, 422 (104 males, 318 females) with PM, and 290 (175 males, 115 females) with IBM who resided in the U.S. at diagnosis.

Data collection

Participants completed self-administered questionnaires with incomplete responses queried by telephone interview as needed. The questionnaire included general social and demographic factors (sex, race/ethnicity, education), questions about myositis clinical features and diagnosis date, residence at the time of diagnosis, questions about sun sensitivity and determinants of personal UV exposure, including the number of sunburns in the 12 months prior to diagnosis (none, 1,2,3, and >3 times), color of untanned skin (fair, olive, light brown, dark brown, very dark), and sun sensitivity (i.e., how would their skin react if exposed to strong sunlight for more than an hour without sunscreen: severe sunburn with blisters, painful sunburn without blisters, mild sunburn followed by tanning, become tanned without any sunburn, or no visible reaction).

A detailed job history included questions about specific jobs held for more than one year, including work on a farm or orchard, landscaping, building or road construction, painting houses, or police/firefighting/other first responder. For each job, participants were asked what year they started, and if they were still currently working at that job or the year the work ended. Participants were also asked about factory work, whether they worked in production or an office environment, and specifically what type of factory.

A history of outdoor hobbies or leisure activities before the diagnosis of myositis was also collected. Participants were asked how much time they spent gardening and engaging in outdoor activities, such as swimming, tennis, hiking, or boating, and any other hobby or leisure activity, before diagnosis. Participants were asked to specify which activity they did the most before diagnosis, what year they began that activity, and whether they were still doing it or what year they stopped. Participants provided the number of hours per week and months per year in which they engaged in each activity.

Assessing individual-level sun exposures

Personal sun exposures were assessed for all reported jobs and hobbies, which were ranked according to their potential for high-intensity UV exposure. We assessed job- and hobby-related exposures that were deemed to be greater than the exposures typically experienced in everyday life, and developed a matrix to systematically rate the jobs and hobbies for regular intense sun exposure (Supplemental Table 1A). Other jobs were individually evaluated by expert assessment (CP, KR) and resolved through consensus, including additional reviewers

(LR, AF, PNF) and literature review. Ratings were assigned without knowledge of IIM phenotype or timing of the job relative to diagnosis. Each rating was also assessed as being made with high or low certainty.

Summary exposure variables were derived to reflect the highest potential exposure from jobs and hobbies in the year prior to diagnosis. Individuals were grouped, giving greater weight to jobs due to the generally longer hours compared with hobbies (Supplemental Table 1B): with 4 ranked groups, including high, high-moderate, moderate, and low/no. Due to the small number of individuals with high-only and high-moderate exposures, these were combined to enable stratified analyses. Because early symptoms might lead to changes in occupational or recreational behaviors, sensitivity analyses were also performed, including exposures up to 2 years prior to diagnosis.

Assessing ambient UV exposures

Average and maximum ambient UVB irradiance was determined using data from the Total Ozone Mapping Spectrometer (TOMS), which collects ozone and reflectivity data to estimate surface exposure intensity as Joules/m^2 (14). The ZIP code of each subject's residence at diagnosis date was used to identify the geographic location of cases. We estimated maximum UV daily dose in the year prior to diagnosis, averaged by geographic region, as a predictor of the proportion of DM cases in participants with adult IIM.

Population sunburn prevalence

For comparison with a population sample, we obtained national estimates of sunburn in the past 12 months in the U.S. population from 1999, 2003, and 2004 based on data from the Behavioral Risk Factor Surveillance System (BRFSS) surveys (15). In BRFSS, sunburn was defined as "anytime that even a small part of your skin stayed red for more than 12 hours."

Analyses

Analyses focused on individual-level job and hobby exposures and sun-related personal characteristics in the year prior to diagnosis, along with analyses of ambient UV exposure levels comparable with prior studies. We examined participant characteristics and generated frequencies stratified by reported sunburn in the year prior to diagnosis. Associations of DM with sunburn and personal sun-exposure level were then evaluated using logistic regression to estimate odds ratios (OR) and 95% confidence intervals (CI) adjusted for age, skin tone, and sex. Socioeconomic status based on census data did not confound effect estimates (i.e., inclusion did not change effect estimates by >10%; results not shown), so was not included in the final models. Race was correlated with skin tone, so was not considered as a potential confounder. Given established differences in the frequency of sunburn and sun-protective behaviors (16), as well as likely differences in occupational activities given the same job title, we initially ran models separately for men and women and tested for interactions, comparing the −2 Log Likelihoods for models with and without the product terms (sex X sun exposure variables). Despite differences in job- and hobby-related sun exposures and IIM phenotype by sex (Supplemental Table 2), interaction terms were not significant. Therefore, overall results are shown adjusted for sex as a covariate. Sensitivity analyses

excluded (i) participants reporting sunburn in the past year and (ii) those with low certainty exposures.

For ambient UV exposure, weighted regression models were run overall and stratified by sex and in whites, to compare participants with DM versus PM. The sample was too small to estimate associations in non-whites. We then explored whether maximum residential UV levels and sun sensitivity modified DM associations with personal sun exposures and assessed potential for statistical interaction as previously described.

Finally, we calculated the unadjusted and age-adjusted prevalence of sunburn in the 12 months prior to diagnosis in participants with IIM diagnosed between 1999 and 2004, overall, and in those with DM, PM, and IBM. Age-adjusted prevalence was then compared with sunburn in the U.S. population based on BRFSS estimates during the same period. We also made comparisons among females only, due to the observed higher rates of sunburn in female DM cases and associations of DM with sunburn and higher ambient UV exposure in females.

Results

Table 1 shows the study sample characteristics by DM versus PM/IBM phenotype, stratified by sunburn in the year prior to diagnosis. Individuals who reported sunburn tended to be younger regardless of IIM phenotype, and sunburn was more common in females with DM. Most participants were non-Hispanic white, and whites with IBM or PM were more likely than non-whites to report sunburn. Participants who reported sunburn were more likely to report a fair skin tone and a tendency to experience severe sunburn, regardless of IIM phenotype. The study sample included individuals from across the U.S. Geographic region was related to sunburn history only in participants with DM. Supplemental Table 2 shows participant characteristics by phenotype (DM, PM, and IBM) stratified by sex, with unadjusted comparisons across all three phenotypes.

History of sunburn in the year prior to diagnosis was reported by 42% of participants with DM compared with 28% with PM/IBM, and sunburn was associated with DM adjusting for diagnosis age, sex, and skin tone (Table 2): The association was somewhat stronger for reporting two or more sunburns (odds ratio [OR]=1.77; 95% confidence interval [CI] 1.28, 2.43; P=0.0005), but remained elevated and statistically significant for one sunburn (OR=1.44; 95%CI 1.06, 1.95; P=0.018). High or moderate level occupational sun exposure was seen in only 15% of respondents regardless of IIM phenotype. In adjusted models, an elevated, but not statistically significant association, was seen between DM and high or moderate level occupational sun exposure (OR=1.36; 95% CI 0.96, 1.93 versus low or no exposure). By contrast, recreational sun exposure was common (67% of DM participants) and was significantly associated with DM (OR=1.34; 95% CI 1.05, 1.73). The association of DM with sun exposure from jobs or hobbies combined was greatest for the highest exposures (High/Moderate-High; OR=1.64; 95% CI 1.08, 2.49), but was also elevated for moderate level exposure (OR=1.35; 95%CI 1.02, 1.78).

Sex differences in associations with the DM phenotype were not statistically significant, although qualitative differences were seen (Supplemental Table 3). The association of DM with sunburn history was more apparent in females (OR 1.98; 95% CI 1.36, 2.89 for 2 or more sunburns versus none), while occupational sun exposure was associated with DM primarily in males (High/Moderate vs. Low/No OR=1.70: 95% CI 1.00, 2.90). Associations of personal sun exposure and DM were somewhat stronger in analyses excluding participants whose exposures were rated with low certainty (Supplemental Table 4), and results were similar when including exposures up to 2 years prior to diagnosis (Supplemental Table 5) or excluding those with a history of sunburn in the year prior to diagnosis (Supplemental Table 6).

The association of DM with sunburn history did not vary by maximum ambient UV level (Table 3), but the ORs for DM with high and moderate level personal sun exposure were statistically significant only in participants living in areas with higher ambient UV levels. In models stratified by sun sensitivity (tendency to experience severe or painful sunburns), the associations of DM with sunburn history and personal sun exposures were statistically significant only in those reporting lower sun sensitivity (Table 4). Although interaction terms were not statistically significant, there was a tendency toward sun sensitivity modifying the association of DM with moderate personal sun exposure (P=0.129).

Figure 1 depicts the association of DM and maximum daily UV dose across geographic regions. Weighted linear regression models of this association showed no overall statistically significant difference in the proportion of DM among adults with IIM associated with a one-unit increase in maximum UV dose-rate in the year before diagnosis (Table 5). However, the proportion of DM associated with elevated UV dose was higher in females (beta=3.97, P=0.046). Models restricted to whites did not show significant associations.

Comparing the prevalence of sunburn reported in the 12 months prior to diagnosis among participants in the MYOVISION registry (diagnosed 1999 to 2004) with population rates reported in the BRFSS, no overall difference was seen (Supplemental Table 7). However, females with DM had a higher age-adjusted prevalence of sunburn than females in the BRFSS survey (30.7% versus 23.5%, P=0.015).

Discussion

MYOVISION is the largest registry of myositis patients in the United States. It includes comprehensive questionnaire data about jobs and hobbies, potential confounders, and susceptibility factors. Using these data, we conducted a blinded and systematic assessment of personal sun exposures to identify individuals with higher potential for intense UV exposure in the year prior to their diagnosis. Our findings support the hypothesis that UV exposure modulates IIM phenotype and influences the risk of developing DM, and they provide evidence that individual-level factors related to personal sun exposure are associated with the probability of developing DM compared to other myositis phenotypes.

Previous studies evaluated residential UV exposure intensity in the year prior to diagnosis, based on ground surface measurements of UV radiation, to study associations of ambient

UV with DM compared to PM and in relation to myositis autoantibodies associated with DM (7–9). Based on geographic exposure data, we did not observe significant overall variation in the proportion of DM cases by maximum UV level. However, the proportion of DM was significantly associated with ambient UV exposures among female participants. These findings are consistent with an earlier study of 320 U.S. myositis patients that reported the association of ambient UV intensity in which the DM phenotype (compared with PM) and anti-Mi-2 autoantibodies were most apparent in women (7). Taken together, this evidence supports the investigation of sex differences in the relationship between ambient UV and DM.

Gender differences in sunburn and sun-protective behaviors have been observed in U.S. whites, the general population, and outdoor workers, including a male predominance in sunburn and females engaging in more protective behaviors (17, 18). In our sample, sex-interactions with sunburn and job-related sun exposure were suggestive (at $P<0.20$). Men were more likely than women to have occupational exposures, and the association with job-related sun exposure and DM was statistically significant in men and not seen in women. On the other hand, the association of sunburn with DM was stronger in women. Females with DM were more likely to report fair skin tone and a tendency for severe or painful sunburns (Supplemental Table 2). There is increasing evidence of sex-related differences in the immune effects of UV radiation: white males appear to have greater sensitivity to UV-induced immunosuppression (19, 20); however, in an animal model of melanoma, females showed a stronger initial response to lower UV doses (21). In systemic lupus erythematosus (SLE), female patients are more likely than males to experience photosensitivity (22). A larger sample is needed to disentangle sex differences in sun exposure from differences in responsiveness to ambient UV.

When the ambient UV level is higher, it takes less unprotected time in the sun to initiate a damaging skin response. Therefore, we also used data on ambient UV to explore the role of personal sun exposures. While ambient UV level did not modify the association of the DM phenotype with sunburn or higher personal sun exposure level, the association with moderate levels of personal sun exposure was more apparent in participants residing with higher ambient UV levels. Sun protective behaviors may depend on the intensity of exposure and time spent outdoors, and we saw no difference in the association of sunburn with DM by ambient UV.

Surprisingly, the association of sunburn with DM was more apparent in individuals reporting a tendency towards lower sun sensitivity (i.e., mild sunburn, tanning, or no reaction to sun exposure rather than severe sunburn). We also saw a stronger association of DM with job- and hobby-related exposures in those reporting lower sun sensitivity. These seemingly counterintuitive findings differ from a study of SLE patients in which those with the strongest reaction to midday sun were at increased risk compared to a control sample (23). Many factors influence sun susceptibility and behaviors determining an individual's actual level of exposure. We saw expected associations between sunburn (and sun exposure) with age, gender, and skin tone. We did not collect data on sun-protective behaviors, but surmise that those reporting low sun sensitivity may be less likely to use protective measures, whereas those who typically experience painful and severe sunburns may avoid exposures to

intense sun or take more precautions when exposures are unavoidable. Our comparison sample was patients with different myositis phenotypes, rather than non-diseased controls as in the aforementioned study of SLE. Also, registry participants were from a broad geographic region at a lower latitude.

The role of UV radiation in a wide range of autoimmune diseases has long been a topic of interest, and UV has been proposed as a potential protective factor in multiple sclerosis and rheumatoid arthritis and as a risk factor in SLE (24–26). Exposure of skin to UV-B is associated with sunburn and skin damage and has diverse effects on the immune system, including effects on both the skin itself and systemic effects (27). Low-dose UV-B exposure may have an immune-suppressive effect, protecting against autoimmune diseases. Conversely, there are multiple mechanisms that may contribute to acute effects of intense UV exposure on the development of an autoimmune response (28), including increased reactive oxidative species, damage to DNA and apoptosis leading to cellular debris and other changes; high doses of UV-B and sunburn can trigger an immune response to neoantigens, and sunburn itself is an acute inflammatory response to cutaneous damage induced by high UV exposures (28, 29). We hypothesized that these types of high-intensity exposures were more relevant to the development of the DM phenotype, whereas lower-level exposures with protective effects might act similarly across multiple phenotypes. While our findings do not directly address mechanisms, they support the investigation of mechanistic pathways by which UV may induce the DM phenotype.

Our study has several limitations. First, the registry is a volunteer sample that may not reflect IIM cases in the general population. Disease severity and self-awareness/advocacy could impact our results to the extent that these factors might have influenced participation in the registry. Also, participants were identified based on self-report and confirmed by expert review, but no additional data on disease subtypes were available. Serum was not available from registry participants, so testing for myositis specific autoantibodies was not performed to assess anti-Mi-2 or anti-p155/140 (TIF-1) autoantibodies, previously associated with exposure to UV radiation and the DM phenotype (7–9). Cases were eligible for the registry based on Bohan and Peter criteria for DM and PM, which are focused on muscle criteria and may miss cases with classic skin symptoms who do not meet these full criteria. Patients with amyopathic or hypomyopathic DM were not included in our sample, but may be important to consider in the spectrum of environmental UV exposure and IIM, as they are more likely to be photosensitive (5, 30). As with any retrospective study, differential recall is possible, especially for sunburn and sun sensitivity, given the characteristic rashes in DM. We did not adjust for sunburn in models of sun exposure variables since sunburn could be a trigger for DM on the causal pathway. Patients with DM may have been counseled to avoid sun exposure and use sunscreens, which could influence their recall and reporting of sunburn. Sunburn history might also influence recall of outdoor hobbies, while reporting of jobs and residential location is more likely to be objective.

Our findings may be subject to exposure misclassification bias. The use of geographic location to assess ambient UV exposure is intrinsically subject to error due to variations in personal exposures. Therefore, we utilized extensive individual-level data to improve exposure estimates. The assessments of sun exposure for a specific job or activity are also

prone to error, but our findings were unchanged (and possibly stronger) when individuals with low certainty exposure estimates were excluded. The unexposed referent group is likely to contain some individuals with intense exposures not captured by the questionnaire (for example, travel to a sunny location, sunbathing, or the use of tanning salons). These types of exposures were not included in our questionnaire, along with a lack of data on photoprotective measures. Because we hypothesized that exposure intensity would be a trigger for DM proximal to diagnosis, we did not consider exposure duration. The timing of causally relevant exposures prior to symptom onset and disease diagnosis is not known; however, given the mechanisms of acute damage and immune effects described above, a shorter window of exposure prior to diagnosis seems reasonable. On average, the median time to diagnosis is less than 1 year for DM and PM (median 5 months to diagnosis for DM, and 8 months for PM), while IBM is considerably longer (5). We did not have information on the time of symptom onset relative to diagnosis; however, findings were similar for exposures up to 2 years prior to diagnosis.

In conclusion, our findings provide preliminary evidence that an individual's exposures to UV radiation through job- and hobby-related sun exposures may influence the risk of developing DM. Further research is needed on the role of individual susceptibility and sun-protective behaviors in the risk of DM, and to compare DM patients with population controls.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Significance and Innovation

- Based on questionnaire data from a United States national myositis patient registry, dermatomyositis, as compared to polymyositis and inclusion body myositis, is associated with sunburn and moderate to high job-related sun-exposure in the year prior to diagnosis.
- This study confirms prior findings that ambient ultraviolet radiation exposure is associated with dermatomyositis in females.
- Taken together, this evidence suggests that personal exposure to environmental ultraviolet radiation may be a modifiable risk factor for dermatomyositis.

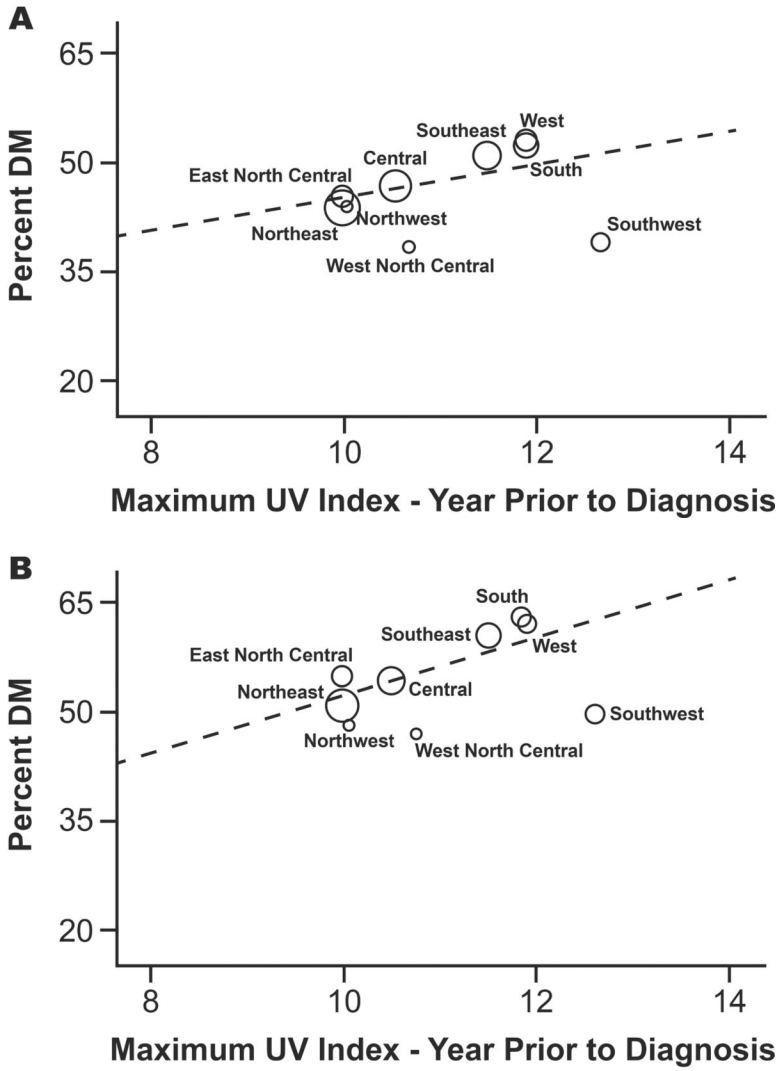

Figure 1.

Ambient UV radiation by geographic region and percentage of adult dermatomyositis (DM) among U.S. adults with idiopathic inflammatory myopathies (IIM) in the MYOVISION registry, (A) Overall, and (B) Females only. The size of the circle representing each region is proportional to the number of patients residing in the area in the year prior to diagnosis. Regions are based on geoclimatic zones ((http://www.ncdc.noaa.gov/temp-and-precip/us-climate-regions.php): Northeast (ME, DE, DC, MD, MA, NJ, NY, PA, RI, NH, CT, VT), East North Central (IA, MI, MN, WI), Southeast (AL, FL, GA, NC, SC, VA), South (AK, KS, LA, MS, OK, TX), West North Central (ND, SD, MT, NE, WY), Central (IN, KY, OH, TN, WV, MO, IL), Northwest (WA, OR, ID), West (CA, NV), Southwest (AZ, NM, CO, UT).

Abbreviations: PM, polymyositis; IBM, inclusion body myositis; UV, ultraviolet radiation.

Table 1

Characteristics of participants with dermatomyositis (DM) vs. polymyositis (PM) and inclusion body myositis (IBM) stratified by history of sunburn in the year prior to diagnosis in the MYOVISION national myositis patient registry

	DM		PM+IBM	
	Sunburn*	No Sunburn	Sunburn	No Sunburn
	n=264	n=368	n=200	n=511
Participant characteristics	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Age				
Median [IQR], years	44 [35, 52]	48 [38, 55]	50 [42, 56]	54 [45, 61]
P	<0.0001		<0.0001	
Sex				
Female	229 (87)	297 (81)	122 (61)	311 (61)
Male	35 (13)	71 (19)	78 (39)	200 (39)
P	0.045		0.97	
Race/ethnicity				
White, Non-Hispanic	231 (88)	310 (84)	185 (93)	422 (83)
Black/Other	33 (13)	58 (16)	15 (8)	89 (17)
P	0.25		0.0008	
Skin tone†				
Fair	196 (75)	233 (63)	151 (76)	343 (67)
Olive to very dark	67 (25)	135 (37)	47 (24)	167 (33)
P	0.003		0.019	
Skin reaction to sunlight‡				
Severe sunburn	112 (42)	116 (32)	75 (38)	146 (29)
Mild sunburn	139 (53)	163 (44)	108 (54)	222 (44)
Tanned or no reaction	13 (5)	88 (24)	17 (9)	142 (28)
P	<0.0001		<0.0001	
Geographic region§				
Northeast	55 (21)	90 (25)	50 (25)	134 (27)
South	26 (10)	47 (13)	20 (10)	45 (9)
Southeast	50 (19)	65 (18)	28 (14)	89 (18)
Central	62 (24)	50 (14)	34 (17)	85 (17)
East North Central	21 (8)	35 (10)	22 (11)	47 (9)
West	29 (11)	34 (9)	20 (10)	45 (9)
Southwest	7 (3)	21 (6)	13 (7)	28 (6)
Northwest	6 (2)	15 (4)	3 (2)	22 (4)
West North Central	3 (1)	8 (2)	7 (4)	9 (2)
P	0.028		0.49	

Abbreviations: DM, dermatomyositis; PM, polymyositis; IBM, inclusion body myositis; IQR, interquartile range.

*Sunburn in the year prior to diagnosis, n=7 missing (6 DM and 1 PM/IBM).

[†] In the absence of a tan, n=4 missing (1 DM, 3 PM/IBM).

[‡] Skin reaction n=2 missing (1 DM, 1 PM/IBM).

[§] At the time of diagnosis, n=18 missing (8 DM, 10 PM/IBM). Northeast (ME, DE, DC, MD, MA, NJ, NY, PA, RI, NH, CT, VT), East North Central (IA, MI, MN, WI), Southeast (AL, FL, GA, NC, SC, VA), South (AK, KS, LA, MS, OK, TX), West North Central (ND, SD, MT, NE, WY), Central (IN, KY, OH, TN, WV, MO, IL), Northwest (WA, OR, ID), West (CA, NV), Southwest (AZ, NM, CO, UT)

Table 2.

History of sunburn and personal sun exposures in the year prior to diagnosis: frequency and association with dermatomyositis (DM) phenotype*

	DM n (%)	PM/IBM n (%)	DM vs. PM/IBM OR (95% CI)†	P
Sunburn (year prior to dx)				
≥ 2 sunburns	133 (21)	91 (13)	1.77 (1.28–2.43)	0.0005
1 sunburn	130 (21)	107 (15)	1.44 (1.06–1.95)	0.018
No sunburn	368 (58)	510 (72)	1.00 (REF)	
Job-related sun exposure				
High/Moderate	86 (15)	94 (15)	1.36 (0.96–1.93)	0.081
Low/None	493 (85)	544 (85)	1.00 (REF)	
Hobby-related sun exposure				
High/Moderate	382 (67)	391 (61)	1.34 (1.05–1.73)	0.021
Low/None	187 (33)	251 (39)	1.00 (REF)	
Combined sun exposure				
High/Moderate-High	73 (14)	79 (14)	1.64 (1.08–2.49)	0.020
Moderate	293 (56)	292 (51)	1.35 (1.02–1.78)	0.036
Low/None	156 (30)	206 (36)	1.00 (REF)	

Abbreviations: DM, dermatomyositis; OR, odds ratio; PM, polymyositis; IBM, inclusion body myositis; CI, confidence interval; REF, referent group.

*Percent for each excludes missing values: Job-related, n=136 missing (64 DM, 71 PM/IBM) and hobby-related exposures, n=132 missing (64 DM, 68 PM/IBM).

†Odds ratios and 95% confidence intervals were adjusted for age at diagnosis, sex, and skin tone.

Table 3.

Prevalence and association of dermatomyositis (DM) with sunburn and sun exposure in the year prior to diagnosis, by maximum ambient ultraviolet radiation (UV) radiation levels based on residential location at diagnosis*

	At or above the median of maximum UV dose				Below the median of maximum UV dose				
Effect	DM n (%)	PM/IBM n (%)	DM vs. PM/IBM OR (95% CI)	P	DM n (%)	PM/IBM n (%)	DM vs. PM/IBM OR (95% CI)†	P	Interaction P
Sunburn									
≥ 2 sunburns	66 (21)	50 (15)	1.52 (0.97–2.38)	0.066	66 (22)	40 (11)	2.05 (1.29–3.27)	0.002	0.468
1 sunburn	63 (20)	47 (14)	1.62 (1.04–2.54)	0.034	61 (20)	58 (17)	1.25 (0.82–1.92)	0.303	0.350
No sunburn	184 (59)	246 (72)	1.00 (REF)		175 (58)	252 (72)	1.00 (REF)		
Combined sun exposure									
High/Mod-High	35 (13)	40 (14)	1.89 (1.03, 3.48)	0.040	35 (14)	39 (13)	1.34 (0.75, 2.41)	0.329	0.673
Moderate	151 (58)	140 (50)	1.64 (1.09, 2.47)	0.017	136 (55)	146 (51)	1.13 (0.76, 1.67)	0.546	0.259
Low/None	75 (29)	98 (35)	1.00 (REF)		78 (31)	104 (36)	1.00 (REF)		

Abbreviations: DM, dermatomyositis; PM, polymyositis; IBM, inclusion body myositis; OR, odds ratio; CI, confidence interval; REF, referent group.

Table 4.

Prevalence and association of dermatomyositis with sunburn and sun exposures in the year prior to diagnosis, by self-reported sensitivity to sun*

	Mild sunburn/tanning/no reaction				Painful or severe sunburn				
Effect	DM n (%)	PM/IBM n (%)	DM vs. PM/IBM OR (95% CI)	P	DM n (%)	PM/IBM n (%)	DM vs. PM/IBM OR (95% CI)†	P	Interaction P
Sunburn									
≥ 2 sunburns	75 (19)	52 (11)	2.05 (1.36–3.09)	0.0006	58 (26)	39(18)	1.17 (0.69–2.00)	0.562	0.219
1 sunburn	77 (19)	71 (15)	1.44 (0.99–2.09)	0.057	53 (23)	36 (16)	1.25 (0.73–2.14)	0.414	0.976
No Sunburn	251 (62)	364 (75)	1.00 (REF)		116 (51)	145 (66)	1.00 (REF)		
Combined sun exposure									
High/Mod-High	48 (15)	55 (14)	1.76 (1.06, 2.91)	0.028	25 (13)	24 (13)	1.74 (0.78, 3.88)	0.177	0.561
Moderate	198 (60)	206 (52)	1.60 (1.13, 2.27)	0.008	94 (49)	86 (47)	0.99 (0.61, 1.61)	0.962	0.129
Low/None	83 (25)	134 (34)	1.00 (REF)		73 (38)	72 (40)	1.00 (REF)		

Abbreviations: DM=Dermatomyositis; PM=Polymyositis; IBM=Inclusion body myositis; UV=Ultraviolet radiation; REF=referent group; Mod=moderate

*Models are limited to participants diagnosed between the ages of 18 and 65 years, and after January 1st, 1990. Total IIM includes dermatomyositis, polymyositis, and inclusion body myositis.

†Odds ratios (OR) and 95% confidence intervals (CI) adjusted for gender, age, and skin tone.

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Table 5.

Weighted linear regression analysis of the change in proportion of dermatomyositis (DM) in adult idiopathic inflammatory myopathy (MM) patients associated with a one-unit increase in maximum ultraviolet radiation (UV) dose-rate in the year before diagnosis

	Proportion of DM to Total IIM (%)		
Patient sample †	**β***	**SE**	**P**
All IIM patients	2.28	1.61	0.200
Female	3.97	1.64	0.046
Male	0.19	1.13	0.868
Non-Hispanic white patients	1.81	1.52	0.274
Female	3.08	2.05	0.177
Male	0.16	0.54	0.781

Abbreviations: DM, dermatomyositis; IIM, Idiopathic inflammatory myopathies; UV, ultraviolet radiation; SE, standard error.

*Change in proportion of DM corresponding to a 1-unit increase in UV index.

†Limited to participants diagnosed between the ages of 18 and 65, and after January 1st, 1990. Total IIM includes dermatomyositis, polymyositis and inclusion body myositis.